**Fishery Data Series No. 05-55**

# Klag Lake Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment Project: 2003 Annual Report and 2001–2003 Final Report

**by**

**Jan Conitz,**

**Margaret Cartwright,**

**Cameron Lingle,**

**and**

**Jack Lorrigan**

**October 2005**

**Alaska Department of Fish and Game** **Divisions of Sport Fish and Commercial Fisheries**

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| milliliter | mL |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| nautical mile | nmi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| degrees kelvin | K |
| hour | h |
| minute | min |
| second | s |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity (negative log of) | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| Alaska Administrative Code | AAC |
| all commonly accepted abbreviations | e.g., Mr., Mrs., AM, PM, etc. |
| all commonly accepted professional titles | e.g., Dr., Ph.D., R.N., etc. |
| at | @ |
| compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| copyright | © |
| corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| District of Columbia | D.C. |
| et alii (and others) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g. |
| Federal Information Code | FIC |
| id est (that is) | i.e. |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S.C. | United States Code |
| U.S. state | use two-letter abbreviations (e.g., AK, WA) |

**Measures (fisheries)**

| | |
|---|---|
| fork length | FL |
| mideye-to-fork | MEF |
| mideye-to-tail-fork | METF |
| standard length | SL |
| total length | TL |

**Mathematics, statistics**

| | |
|---|---|
| *all standard mathematical signs, symbols and abbreviations* | |
| alternate hypothesis | $H_A$ |
| base of natural logarithm | *e* |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, etc.) |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular ) | ° |
| degrees of freedom | df |
| expected value | *E* |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_2$, etc. |
| minute (angular) | ' |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | $\alpha$ |
| probability of a type II error (acceptance of the null hypothesis when false) | $\beta$ |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| variance | |
| population | Var |
| sample | var |

# *FISHERY DATA SERIES NO. 05-55*

# KLAG LAKE SOCKEYE SALMON *(ONCORHYNCHUS NERKA)* STOCK ASSESSMENT PROJECT: 2003 ANNUAL REPORT AND 2001–2003 FINAL REPORT

By
Jan Conitz,
Margaret Cartwright,
Cameron Lingle
Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau
and
Jack Lorrigan
Sitka Tribe of Alaska, Natural Resources, Sitka

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599
October 2005

The Klag Lake Subsistence Sockeye Salmon Project (Study Number FIS01-128-1) was approved by the Federal Subsistence Board, managed by US Fish and Wildlife Service's Office of Subsistence Management, funded by the U.S. Forest Service, and is a cooperative project between the U.S. Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Sitka Tribe of Alaska (STA). This annual and final report completes contract obligations for Sikes Act Contract Numbers 43-0109-2-0216 (ADF&G) and 53-0109-2-00592 (STA).

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

*Jan Conitz,,*
*Margaret Cartwright*
*and*
*Cameron Lingle*
*Alaska Department of Fish and Game, Division of Commercial Fisheries,*
*P.O. Box 240020, Douglas, Alaska, USA,*
*and*
*Jack Lorrigan,*
*Sitka Tribe of Alaska, Division of Natural Resources*
*456 Katlian St., Sitka, Alaska, USA*

*This document should be cited as:*
*Conitz, J. M., M. Cartwright, C. Lingle, and J. Lorrigan. 2005. Klag Lake Sockeye Salmon (Oncorhynchus nerka) Project: 2003 Annual Report and 2001–2003 Final Report. Alaska Department of Fish and Game, Fishery Data Series No. 05-55, Anchorage.*

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

**Figure** **Page**



# LIST OF APPENDICES

**Appendix** **Page**

# ABSTRACT

From 2001–2003, we estimated sockeye salmon (*Oncorhynus nerka*) escapement into Klag Lake, sockeye harvest in subsistence and sport fisheries in Klag Bay, and certain measures of freshwater productivity. In this report, we present results from 2003, compare them with published results from 2001 and 2002, and examine patterns in findings for all three years. Estimated escapement into Klag Lake was 23,000 sockeye salmon in 2003, up from 17,000 in 2002 and 12,000 in 2001. In 2003, subsistence fishers harvested about 2,400 sockeye salmon and 100 fish were taken in the sport fishery. The 2003 sockeye subsistence and sport harvest was lower than the 2002 harvest (3,000 fish), but higher than the 2001 harvest (1,700 fish). Sockeye harvests in 2001–2003 were not large relative to sockeye escapements in those years (9–15% of the total sockeye return), indicating these harvest levels are reasonable. However, harvest timing may disproportionately harvest more fish in the early part of the run. In 2002 and 2003, over 2,000 fish were harvested before equivalent numbers entered the lake as escapement. Seasonal mean zooplankton biomass increased from 175 $mg{\cdot}m^{-2}$ in 2001 to 222 $mg{\cdot}m^{-2}$ in 2002 to 316 $mg{\cdot}m^{-2}$ in 2003. The cladoceran (*Daphnia longiremis*), the preferred food of sockeye fry, represented only about 2% of the total seasonal mean zooplankton biomass over the three years. Individual *D. longiremis* were smaller on average in 2003, having an average length of 0.7 mm, compared with 0.8 mm in the previous two years. We recommend continuing in-season assessment of sockeye returns to Klag Lake to ensure the escapement is adequate and proportional to the natural timing of the run.



Key words: Sockeye salmon, *Oncorhynchus nerka*, subsistence, Chichagof Island, Klag Lake, Sitka, escapement, fry, mark-recapture, weir, harvest survey, zooplankton.


# INTRODUCTION

Klag Bay (*Kleix'*) belonged, under the traditional Tlingit ownership system, to the Chookeneidi clan of the Sitka Tlingits, and was the site of two villages, called Gagaxli.aan and Dak̲deiyi Aan (Goldschmidt et al. 1998). By the late 1800s the villages were gone, but a few people continued to have houses and smokehouses in this area. One of these residents, Mr. Ralph Young, described the abundant resources his family used from this area:

> We would stay in Sitka during the winter and in the spring and through the summer could fish and hunt at Klag Bay and vicinity… We did our seal hunting—and trapping and hunting for other animals—and got all sorts of seafood and seaweed from all the islands to the westward of these places… I have fished in all these areas during the last forty years…We picked berries from Klag Bay and Slocum Arm… There were halibut banks near Chichagof . [The stream in Klag Bay] was our one sockeye stream that gave us all the sockeyes we needed" (R. Young in Goldschmidt et al. 1998).

Sockeye (*Oncorhynchus nerka*) lakes were prized possessions among the Tlingit people, and higher status clans had the prestige and responsibility of managing fishing on these systems. Sitka clans claimed ownership rights to the productive sockeye system at Klag Bay. A conflict over ownership rights to the Klag Lake sockeye stream occurred in the early 1900s when clan owners tried to post the stream to keep commercial fishermen and other newcomers out; Dundas Bay cannery owners, backed by officials of the U.S. Government, objected and ordered the clan to remove their signs. The discovery of gold by Mr. Young in the late 1800s also brought mining, white settlement, and commerce to Klag Bay. Chichagof village, at the head of Klag Bay, was established in about 1905, received a U.S. Post Office in 1909, and by 1943 had a store, a stamp mill, and a dock (Orth 1971). The Chichagof and other gold mines in the vicinity shut down after World War II, and Chichagof village gradually disappeared. Throughout the gold mining and early commercial fishing period, people from Sitka related to traditional clan owners continued to travel to Klag Bay to fish for sockeye salmon and harvest other subsistence resources. During this period, however, clan ownership lines became blurred by intermarriage to the extent that “all the people from Sitka who are Tlingit Natives are allowed to share in the food supply of the various clans” (R.Young in Goldschmidt et al. 1998).

Currently, Klag Lake is one of the larger producers of sockeye salmon in Southeast Alaska and is second or third in importance to Sitka residents, after Necker Bay and, depending on the season, Redoubt Lake. The abundance of Redoubt Lake sockeye salmon has fluctuated a great deal in recent times (Geiger 2003). In years when sockeye returns to Redoubt Lake are low and conservation measures are in place, subsistence users rely more heavily on the Klag Lake sockeye resource. Fisheries managers became concerned about increasing effort and large sockeye harvests in Klag Bay in some seasons. In the absence of adequate estimates of abundance for Klag Lake sockeye salmon, an Alaska Department of Fish and Game (ADF&G) Sitka Area Management biologist implemented conservative management practices when fishing effort appeared to be high. For example, he closed the subsistence fishery early in 1997, after observing few fish in the system during aerial surveys (Dave Gordon ADF&G Division of Commercial Fisheries, personal communication 2005). In 2000, the Sitka Tribe of Alaska, the U.S. Forest Service, and ADF&G responded to reports by fishermen and biologists about possible over-harvesting of Klag Lake sockeye stocks, and initiated a three-year sockeye monitoring project at Klag Lake.

ADF&G has compiled subsistence fishery data since 1985 from subsistence permit holders who returned their harvest information at the end of the season or upon requesting a permit for the following season. It appears from these data that the overall annual harvest and the average harvest per permit has increased since the 1990s (Appendix A1). For the 10-year period, 1994–2003, the average annual harvest of sockeye salmon from Klag Bay tripled from what it was in the preceding period, 1985–1993, and the number of permits issued annually for Klag Bay doubled over the same period. The average number of sockeye salmon harvested per permit increased from 23 to 30 since the mid-1980s. These reported annual harvest totals do not necessarily represent the actual sockeye harvest, because ADF&G does not independently verify the user-reported harvest numbers. Evidence from the few subsistence sockeye systems in which on-site harvest surveys have been conducted shows that harvest is typically, but not always, under-reported; the degree of under-reporting appears to be highly variable (Conitz and Cartwright 2003; Lewis and Cartwright 2004; Lorrigan et al. 2004).

A cannery at nearby Ford Arm was in operation from 1911 through 1924 (Rich and Ball 1933; Conitz and Cartwright 2002). During this period, sockeye salmon were commercially harvested in Klag Bay. Since that time, there has been no directed commercial fishery in the Klag Bay terminal area. The modern Khaz Bay commercial purse seine fishery normally opens in late July and includes Khaz Bay (sub-district 113-71), Sisters Lake and Lake Anna, and Slocum Arm (sub-district 113-73), but Klag Bay is normally closed at the narrows that separate it from the outer Khaz Bay (Dave Gordon ADF&G Division of Commercial Fisheries, personal communication 2005). Commercial seiners primarily target pink (*O. gorbuscha*) and chum (*O. keta*) salmon, and usually catch very few sockeye salmon (Appendix A2; ADF&G Commercial Fisheries database 2005). The highest sockeye harvests on record in the Khaz Bay seine fishery were 1,534 sockeye salmon in 1996 and 1,960 sockeye salmon in 1997. However, the Klag Lake sockeye stock caught in the commercial fishery cannot be distinguished from sockeye salmon returning to other systems.

Before the start of the Klag Lake subsistence sockeye salmon project, the only escapement data available for Klag Lake were aerial survey counts for some years. No information was available on the juvenile sockeye populations or their rearing habitat prior to this study. The Klag Lake subsistence sockeye salmon project focuses on obtaining accurate sockeye escapement estimates annually—using a weir and mark-recapture methods to confirm the weir count. Another important project objective was to obtain accurate estimates of the sockeye harvest and effort information using direct observation and interviews on the fishing ground site. We assessed the small pelagic fish populations in Klag Lake, including sockeye fry, in 2001 and 2002. Ecological data, including zooplankton species assemblages and abundance and seasonal lake temperatures, dissolved oxygen levels, and irradiance, were collected in 2001–2003.

We report on the first three years of study for this project (2001–2003) in this paper. We present results from 2003 and a synthesis of results from all three years, 2001–2003, with recommendations for management and future study of this important subsistence sockeye system in the Sitka area (Figure 1).

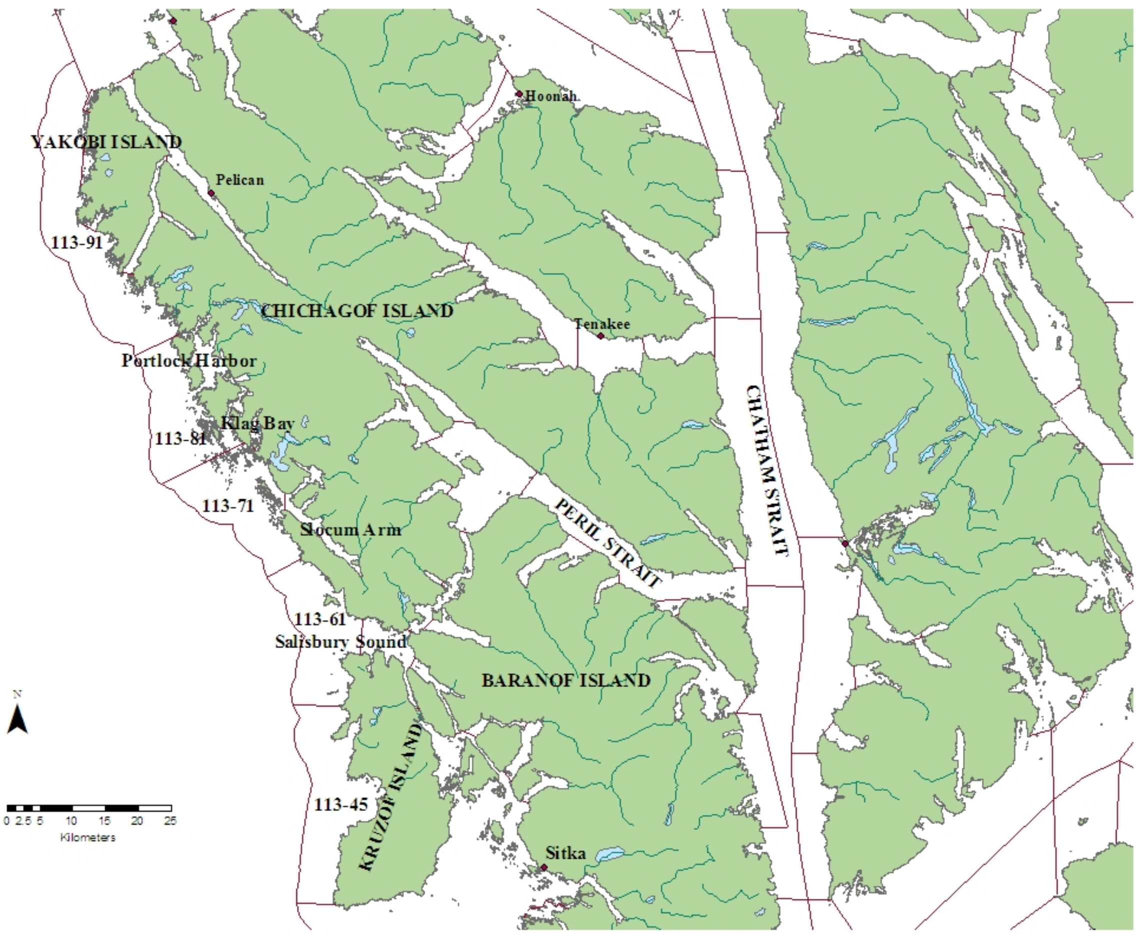


**Figure 1.–**Location of Klag Bay on Chichagof Island. The town of Sitka and commercial fishing districts along the outside coast of Chichagof Island are also shown.

# OBJECTIVES

1. Estimate the escapement of sockeye salmon into Klag Lake, using a weir on the outlet stream of the lake with mark-recapture sampling on the spawning grounds, so that the estimated coefficient of variation is less than 10%.
2. Estimate the subsistence harvest of sockeye salmon from the terminal marine area around the mouth of the Klag Lake outlet stream, using direct observation and on-site interviews, so that the estimated coefficient of variation is less than 15%.
3. Estimate the age, length, and sex composition of the sockeye salmon in the Klag Lake escapement.
4. Estimate the productivity of Klag Lake using established ADF&G limnological sampling procedures.

# METHODS

## STUDY SITE

Klag Bay (N 57$^{o}$ 38.5’, W 136$^{o}$ 42.2’) is the outermost bay in a system of inland saltwater bays or lagoons, which also includes Lake Anna and Sister Lake. Klag Lake receives drainage from approximately seven square kilometers of sparsely wooded low hills, large areas of muskeg, and numerous small shallow lakes and ponds with a maximum elevation of 550 m. With a chain of small lakes streams and ponds to the northeast, Klag Lake has only one active salmon spawning stream. Many smaller streams drain into the lake but we did not observe any anadromous salmon spawning in these streams. Sockeye salmon are blocked from further upstream migration in the main stream by a 1.3 m high barrier falls approximately 500 m upstream, which coho salmon are able to breach. The lake itself is at a 12 m elevation and has a surface area of 83 hectares; the maximum lake depth is 43 m (Figure 2). The lake drains to the south via an outlet that flows through a series of three large ponds before emptying into the east side of Klag Bay. The extensive network of muskegs and ponds buffers flow through the system. Fish species found in Klag Lake include sockeye (*O. nerka*), pink (*O. gorbuscha*), coho (*O. kisutch*), and chum salmon (*O. keta*), steelhead (*O. mykiss*) and cutthroat trout (*O. clarki*), Dolly Varden char (*Salvelinus malma*), and threespine stickleback (*Gasterosteus aculeatus*).


**Figure 2.–**Bathymetric map of Klag Lake, showing 5 m depth contours and two permanent limnology sampling stations (A and B).

## SOCKEYE ESCAPEMENT ESTIMATES

### Weir Count and Mark Recapture Study

We placed a rigid weir approximately 100 meters from the estuary, in the same location and with the same construction used in 2001 and 2002 (Conitz and Cartwright 2002). Migrating salmon, channeled into a trap, were counted by species and released upstream. We marked 20% of the sockeye salmon passing through the weir as part of a mark-recapture study to determine if the fish passed through the weir undetected. The crew systematically sampled sockeye salmon on a daily basis at the weir for sex, length, and scales, with a sampling goal of 600 sockeye salmon distributed through the run. We operated the weir continuously from 22 June to 13 September 2003.

We used a stratified, two-sample mark-recapture study design to estimate sockeye salmon escapement into Klag Lake (Arnason et al. 1995). The crew marked approximately 20% of the sockeye salmon that they passed through the weir with a primary and secondary mark. The primary mark was an adipose clip and three secondary marks were used throughout the season. Three marking strata, each representing about one-third of the total run, were identified by the secondary marks shown in Table 1.

**Table 1.–**Marking strata used at the Klag Lake weir, with identifying fin clip and dates used.

| Stratum | Fin clip | Dates |
|---|---|---|
| 1 | Left Axillary | 28 June–25 July |
| 2 | Left Ventral | 26 July–10 August |
| 3 | Dorsal | 11 August–13 September |

We conducted the recovery phase of the mark-recapture study on the spawning grounds during the spawning period. The crew sampled and examined sockeye spawners for marks in all visual spawning areas. Both live and dead fish were sampled, without replacement—all sampled fish were given a third mark to prevent re-sampling.

## Data Analysis

Darroch maximum-likelihood and least-squares, Schaefer population, and "pooled Petersen" estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995; for details, refer to www.cs.umanitoba.ca/~popan/). SPAS allows the user to pool together some or all of the capture or recapture strata to get a more precise estimate of escapement, possibly at the expense of some bias. If a simple Petersen method is applied to stratified data that have been pooled, the resulting estimate is called the pooled Petersen estimate (Seber 1982). However, the Petersen estimate can be badly biased when the assumptions of equal probability of capture are violated. Briefly stated, the three assumptions of equal probability of capture are: 1) all fish have an equal probability of capture in the first event, 2) all fish have an equal probability of capture in the second event, and 3) fish mix completely between the first and second event. SPAS provides two types of chi-square tests to test whether the assumptions of equal probability of capture are likely to have been violated. The software developers included the test labeled Complete Mixing to test the assumption that there is no difference in probability of movement for fish marked in any first-event stratum to any second-event stratum. This test is equivalent to testing for a difference in capture probability for fish in the second event. The software developers included the test labeled Equal Proportions to test the assumption that there is no difference in probability of capture for fish marked in the first event. If both tests were significant ($p$-value $\leq 0.05$), we used the less precise Darroch stratified population estimate. If the test statistic from at least one of these tests was not significant ($p$-value $> 0.05$), we concluded that we met the assumptions of complete mixing and equal capture probability. Even if one of the test statistics was significant ($p$-value $\leq 0.05$), we considered this to be insufficient evidence of a problem with the pooled Petersen estimate, and concluded that partial or complete pooling could still be valid (Arnason et al. 1995). Other criteria were also examined, including changes in the escapement estimate after pooling. If pooling led to a small change, we concluded that it was probably safe to pool; however, we interpreted a big change in the estimate as an indication the pooled Petersen estimate may be badly biased. Using the chi-square tests in SPAS as guidelines, we attempted to pool as many strata as possible to increase precision.

When use of the pooled Petersen method was warranted, we used the following method to estimate a 95% confidence interval for escapement size, rather than the method provided in the SPAS software. We let $K$ denote the number of fish marked in a random sample of a population of size $N$. We let $C$ denote number of fish examined for marks at a later time, and let $R$ denote number of fish in the second sample with a mark. The number of fish in the escapement, *N*, is estimated by:

$$\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1.$$

In this equation, *R* is a random variable, and can be assumed to follow a Poisson, binomial, hypergeometric, or normal distribution, depending on circumstances of sampling. When *R* is large compared with the size of the second sample, *C*, its distribution can be assumed to be approximately normal (a practical check is to ensure *R* is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population, *p*, such that $\hat{p} = \frac{R}{C}$. We constructed approximate confidence interval bounds around $\hat{p}$ based on the assumption that *R* follows some sampling distribution. We defined the confidence bounds as ($a_{0.025}$, $a_{0.975}$). The 95% confidence interval bounds for the escapement size, *N*, were estimated by taking reciprocals of the confidence interval bounds for *p*, and multiplying by *K*. That is, confidence bounds for escapement size are estimated by:

$$\left(K \cdot 1/a_{0.975},\ K \cdot 1/a_{0.025}\right).$$

If $\hat{p} \geq 0.1$, and the size of the second sample *C* is at least the minimum listed in Table 2, a 95% confidence interval for *p* is estimated by:

$$\hat{p} \pm \left[1.96\sqrt{\left(1-\frac{C}{\hat{N}}\right)\cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C}\right] \text{, (Seber 1982, eq. 3.4).}$$

**Table 2.–**Sample size criteria for using Seber’s (1982) eq. 3.4 to construct 95% confidence interval for a proportion. For given proportion of marked fish observed in the second sample $\hat{p}$, minimum sizes for the second sample are indicated.

| $\hat{p}$ **or 1-** $\hat{p}$ | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
|---|---|---|---|---|---|
| **Minimum sample size** | 30 | 50 | 80 | 200 | 600 |

Seber’s (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for *p* were found from Table 41 in Pearson and Hartley (1966).

## Escapement Age and Size Distribution

Scales, matched with sex and length data, were collected from adult sockeye salmon at the Klag Lake weir to describe the age and size structure of each population. The sampling goal was 600 fish. Fish were selected systematically (e.g. every fifth fish) to prevent selection bias, throughout the entire run. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were aged by technicians at ADF&G Salmon Aging Laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1-year freshwater and 3-years saltwater; Koo 1962). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mideye-to-tail-fork to the nearest millimeter (mm).

The proportion $p_k$ of each age-sex group $k$ was estimated as $\hat{p}_k$ by the standard binomial formula, with associated standard error (SE), where $n_k$ is the number of samples in age-sex group $k$ and $n$ is the total number of samples aged:

$$\hat{p}_k = \frac{n_k}{n} \text{ and } SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \text{ (Thompson 1992, p. 35–36).}$$

The mean length and associated standard error for age-sex group $k$ were calculated by standard normal methods:

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}} \cdot \sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2} \text{ (Thompson 1992, p. 42–43).}$$

### SUBSISTENCE HARVEST ESTIMATE

We used a one-stage stratified sampling design (Cochran 1977) to estimate sockeye salmon harvest and fishing effort in the subsistence and sport fisheries at Klag Bay. Subsistence fishing was open at the Klag Lake terminal area from 1 June to 25 July and 2 through 31 August 2003. Sport fishing was open during these same periods. The primary sampling unit was boat-parties within a day. This design was appropriate because participating boats could be accurately counted and most parties could be interviewed after they completed fishing. We stratified the data by gear type: hook and line (sport), gillnet (subsistence) and seine net (subsistence). The sampling day included all daylight hours, and the crew was able to monitor the fishery seven days a week. Experience showed that samplers could interview nearly all groups participating in the subsistence and sport fisheries. The exception was those boat parties that chose to leave the area without completing an interview. The crew recorded these as missed interviews. If the sampler was able to estimate a catch from observation or third person reporting, he or she entered the estimate in the comment column.

As a fishing boat entered the area, the sampler contacted the group by radio or by motoring out, gave a short explanation of the creel survey, determined the group's sport or subsistence gear use, and requested that the boat party contact the samplers as they prepared to leave the area so the interview could be completed. Data collected during each interview included angler effort (rod or net hours), gear type used, and harvest by species. If the technician was unable to interview a party because two or more boats were leaving at the same time, he or she randomly chose one boat using a coin toss. Samplers maintained a view of the fishing area during the entire sampling period. Boat parties that left the fishery without being interviewed were counted according to their previously identified sport or subsistence gear use, along with any other known information.

Equations for estimating harvest, catch, and effort in each harvest survey were those for a one-stage direct expansion (access point, completed-trip interview) survey (Cochran 1977; Conitz et al. 2002). We let $h_{gj}$ = harvest on boat $j$ using gear $g$, $m_g$ = number of boat parties interviewed using gear $g$, and $M_g$ = number of boat-parties counted using gear $g$. We estimated the harvest (by species and gear group $g$) as follows,

$$\hat{H}_g = \frac{M_g}{m_g} \sum_{j=1}^{m_g} h_{gj} \, .$$

Letting $\bar{h}_g$ denote the mean harvest per boat for the $g^{th}$ gear group, the variance of the harvest by stratum was estimated as,

$$\mathrm{var}(\hat{H}_g) = (1 - \frac{m_g}{M_g}) M_g^2 \, \frac{\sum_{j=1}^{m_g} (h_{gj} - \bar{h}_g)^2}{m_g (m_g - 1)} \, .$$

If all boat parties in a gear group were interviewed, estimated harvest by species was simply the sum of harvest on individual boats. Effort was estimated similarly, substituting $E$ for $H$ in the equations above. Subsistence total harvest for the season was the sum of harvests for gillnet and seine groups.

## LIMNOLOGY SAMPLING

Limnology sampling was conducted at Klag Lake on 29 June, 6 August, and 12 September 2003. On each sampling date, technicians measured light, temperature, and dissolved oxygen profiles at the main sampling station (A), and collected one zooplankton sample at each station (A and B).

### Light, Temperature, and Dissolved Oxygen Profiles

Underwater light intensity was recorded from just below the surface to the depth where measured intensity was one percent of the surface light reading, at 0.5 m intervals, using a photometer (Protomatic). The vertical light extinction coefficients ($K_d$) were estimated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was defined as the depth to which one percent of the subsurface light [photosynthetically available radiation (400–700nm)] penetrates the lake surface (Schindler 1971), and was calculated from the equation, EZD = 4.6205/ $K_d$ (Kirk 1994).

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (percent of saturation) and absolute (mg $L^{-1}$) values for DO and in ºC for temperature. We measured these lake characteristics at 1 m intervals for the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings et al. 1987).

### Secondary Production

Zooplankton samples were collected at two stations using a 0.5 m diameter, 153-µm mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of 50 m, or 2 m from the bottom of the lake if shallower than 50 m, at a constant speed of 0.5 m $sec^{-1}$. The net was rinsed before removing the organisms, and all specimens were preserved in neutralized buffered 10% formalin (Koenings et al. 1987). ADF&G Commercial Fisheries Limnology Laboratory in

Soldotna, Alaska identified zooplankton subsamples to genus or species, estimated the total number of zooplankton by species and calculated an estimate of zooplankton density and biomass for the whole lake in 2001 and 2002 (Conitz et al. 2002; Koenings et al. 1987). Zooplankton density (individuals per $m^2$ surface area) and biomass (weight per $m^2$ surface area) were estimated by species and by the sum of all species (referred to as total zooplankton density or biomass).

# RESULTS

## SOCKEYE ESCAPEMENT ESTIMATES

### Weir Count and Mark Recapture Estimates

We installed a weir in the Klag Lake outlet stream on 22 June 2003; the first nine sockeye salmon were counted through on 28 June (Appendix B). Sockeye escapement was very light for the next month, with no fish passing the weir on numerous days. On 29 July, rainfall raised the water level in the system and a surge of about 4,600 sockeye salmon passed through the weir. A second peak escapement day occurred on 15 August; these two peak escapements and a smaller peak on 2 September occurred in conjunction with peak water levels in the system (Figure 3). The total count for the 2003 season was 22,799 sockeye salmon. Additionally, we counted 3,681 coho salmon, 34,119 pink salmon, and 14 chum salmon through the Klag Lake weir.

The crew marked 4,634 of the 22,799 sockeye salmon counted through the weir, or about 20% of the escapement at the weir (Table 3). The crew marked a high proportion of the small number of sockeye salmon passing through the weir in the first stratum; in the second and third marking periods, the established marking rate 20% was maintained.

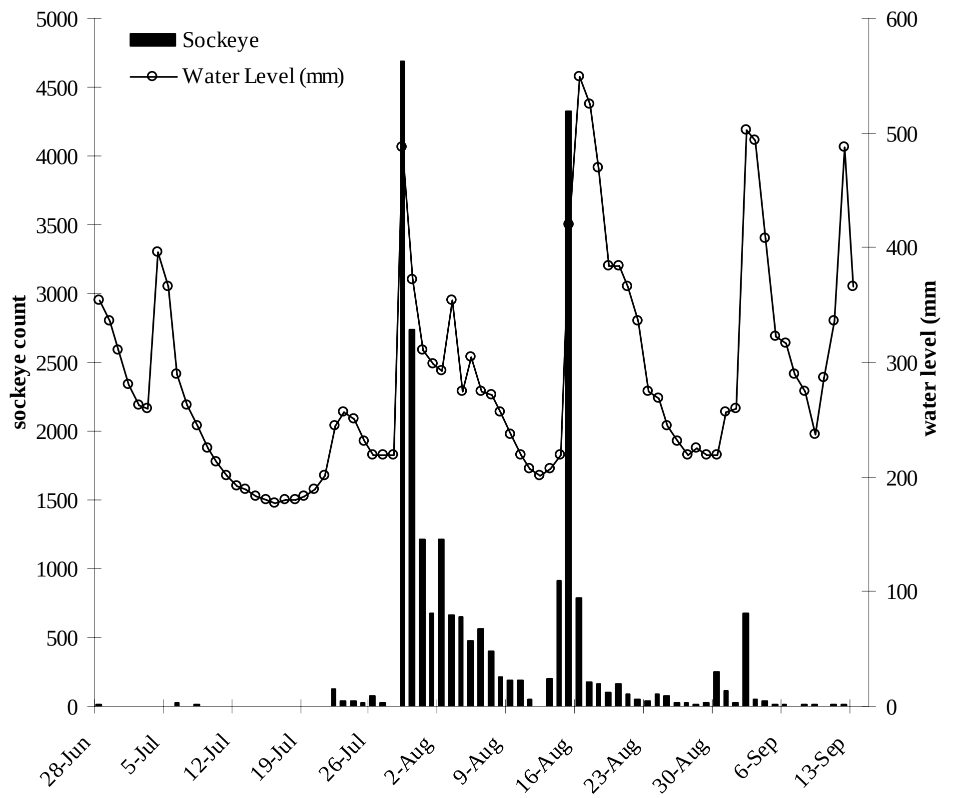


**Figure 3.–**Daily counts of sockeye salmon through the Klag Lake weir and associated water level in the stream near the weir in 2003.

The crew conducted the recovery phase of the mark-recapture study on the spawning grounds between 28 August through 1 September and on 15 September. They sampled 1,587 sockeye salmon, and recaptured 310 marked sockeye fish (Table 3). The first three recapture events were so close together that there was probably no biological difference between them, but because they were during the peak spawning period, it is likely that many new fish immigrated into the spawning stream between each of these three recapture events.

A first analysis with the SPAS program, using three marking strata and four recapture strata designated by the crew, failed to converge upon a maximum-likelihood Darroch estimate. However, one of the chi-square tests, "equal proportions," had a non-significant *p*-value of 0.42 and thus failed to indicate a problem with one assumption of equal probability of capture. Although the test for "complete mixing" was significant at *p*-value<0.01, our criteria indicate that if either one of the tests is non-significant, we have insufficient evidence that we failed to meet assumptions of equal probability of capture and can proceed with pooling in order to increase precision. Because the first marking stratum was too small, and had a marking rate inconsistent with the study design and the other strata, this stratum was an obvious candidate for pooling. Pooling the first and second marking strata (Table 4) permitted the SPAS program to arrive at a valid maximum-likelihood Darroch estimate of 22,947 fish (SE=1,258). Rounding estimate was about 23,000 sockeye salmon (SE=1,300). The chi-square results were unchanged by this partial pooling. The pooled Petersen estimate, in comparison, was 23,666 fish (SE=1,161; 95% CI 21,604–26,303). The rounded pooled Petersen estimates was 24,000 fish (SE=1,200; 95% CI 22,000–26,000). The fact that the Darroch estimate and the pooled Petersen estimate were the same, within the limits of precision of each, provided further evidence there were no detectable problems with mark-recapture assumptions and pooling probably did not lead to bias. Other partial pooling schemes were also considered, such as pooling the first two or three recapture strata, but they did not lead to any improvement in precision or goodness-of-fit according to the chi-square results. The weir count of 22,799 sockeye salmon fell within confidence interval bounds of the pooled Petersen estimate, so we concluded the weir count did not significantly underestimate actual escapement. The weir count was the official escapement number for Klag Lake in 2003.

**Table 3.**–Numbers of sockeye salmon marked at the Klag Lake weir, numbers of sockeye salmon sampled in the spawning stream, and numbers of marked fish recaptured for 2003.

| Phase | Stratum | Dates | Total Marked | | | |
|---|---|---|---|---|---|---|
| Marking | 1 (early) | 28 Jun–25 Jul | 210 | | | |
| | 2 (middle) | 26 Jul-10 Aug | 2,691 | | | |
| | 3 (late) | 11 Aug-13 Sept | 1,733 | | | |
| | | **Total Marked** | **4,634** | | | |
| | | | | **Number recaptures by stratum** | | |
| | | | **Sample Size** | **1** | **2** | **3** |
| Recapture | 1 | 28 Aug | 425 | 11 | 68 | 5 |
| | 2 | 29 Aug | 319 | 2 | 43 | 11 |
| | 3 | 01 Sep | 528 | 0 | 70 | 29 |
| | 4 | 15 Sep | 315 | 0 | 31 | 40 |
| | | **Total Sampled:** | **1,587** | | | |
| | **Total recaptures (all strata):** | | | **310** | | |

**Table 4.–**Partial pooling of recapture strata in Klag Lake 2003 weir mark-recapture dataset.

| Phase | Stratum | Dates | Total Marked | | |
|---|---|---|---|---|---|
| Marking | 1 +2 (early + middle) | 28 Jun–10 Aug | 2,901 | | |
| | 3 (late) | 11 Aug–13 Sep | 1,733 | | |
| | | **Total Marked** | **4,634** | | |
| | | | | **Number recaptures by stratum** | |
| | | | **Sample Size** | **1+2** | **3** |
| Recapture | 1 | 28 Aug | 425 | 79 | 5 |
| | 2 | 29 Aug | 319 | 45 | 11 |
| | 3 | 1 Sep | 528 | 70 | 29 |
| | 4 | 15 Sep | 315 | 31 | 40 |
| | | **Total Sampled:** | **1,587** | | |
| | **Total recaptures (all strata):** | | | **310** | |

## Escapement Age and Size Distribution

The crew collected scales, sex, and length data from 675 sockeye salmon at the Klag Lake weir in 2003. Ages were determined for 638 of the fish that were sampled; scales from the remaining 39 fish could not be aged. As in the previous year, the largest class was age-1.3, comprising 37% of the total sample, and the second largest class was age 1.2 comprising of 23% of the total sample (Table 5). The average mid eye to fork length of all fish in the sample was 515 mm. The age-1.3 fish were largest, with an average length of 553 mm; the older age 2.3 fish were somewhat smaller, averaging 546 mm in length (Table 6). A few jacks, age 1.1 and 2.1 males, were among the sampled fish, with average lengths of 354 mm and 380 mm, respectively.

**Table 5.–**Age and sex composition of sockeye salmon sampled from the Klag Lake escapement in 2003.

| Brood Year | 2000 | 1999 | 1998 | 1999 | 1998 | 1997 | |
|---|---|---|---|---|---|---|---|
| Age | 1.1 | 1.2 | 1.3 | 2.1 | 2.2 | 2.3 | All ages |
| **Males** | | | | | | | |
| Sample size | 25 | 96 | 115 | 8 | 59 | 48 | 351 |
| Percent | 3.9% | 15.0% | 18.0% | 1.3% | 9.2% | 7.5% | 55.0% |
| Standard Error | 0.8% | 1.4% | 1.5% | 0.4% | 1.1% | 1.0% | 2.0% |
| **Females** | | | | | | | |
| Sample size | | 50 | 118 | | 67 | 52 | 287 |
| Percent | 0.0% | 7.8% | 18.5% | 0.0% | 10.5% | 8.2% | 45.0% |
| Standard Error | 0.0% | 1.1% | 1.5% | 0.0% | 1.2% | 1.1% | 2.0% |
| **All Fish** | | | | | | | |
| Sample size | 25 | 146 | 233 | 8 | 126 | 100 | 638 |
| Percent | 3.9% | 22.9% | 36.5% | 1.3% | 19.7% | 15.7% | 100.0% |
| Standard Error | 0.8% | 1.7% | 1.9% | 0.4% | 1.6% | 1.4% | 0.0% |

**Table 6.–**Mean fork length (mm) of sockeye salmon sampled from the Klag Lake escapement in 2003, by sex and age class.

| Brood Year | 2000 | 1999 | 1998 | 1999 | 1998 | 1997 | | |
|---|---|---|---|---|---|---|---|---|
| Age | 1.1 | 1.2 | 1.3 | 2.1 | 2.2 | 2.3 | Not aged | All Fish |
| **Male** | | | | | | | | |
| Av. Length (mm) | 354 | 484 | 554 | 380 | 500 | 548 | 502 | 506 |
| SE (av. length) | 4.0 | 2.8 | 2.3 | 9.9 | 2.6 | 3.6 | 11.4 | 3.1 |
| Sample Size | 25 | 96 | 114 | 8 | 59 | 48 | 24 | 374 |
| **Female** | | | | | | | | |
| Av. Length (mm) | | 494 | 552 | | 495 | 545 | 515 | 526 |
| SE (av. length) | | 2.9 | 1.6 | | 2.6 | 2.5 | 8.5 | 1.9 |
| Sample Size | | 50 | 117 | | 67 | 52 | 15 | 301 |
| **All Fish** | | | | | | | | |
| Av. Length (mm) | 354 | 487 | 553 | 380 | 497 | 546 | 507 | 515 |
| SE (av. length) | 4.0 | 2.1 | 1.4 | 9.9 | 1.9 | 2.1 | 7.7 | 2.0 |
| Sample Size | 25 | 146 | 231 | 8 | 126 | 100 | 39 | 675 |

## SUBSISTENCE HARVEST ESTIMATE

Subsistence fishing opened at the Klag Lake terminal area on 1 June and was closed by emergency order on 25 July 2003 (ADF&G Emergency Order 1-S-47-03); sport fishing was open from 1 January through the 25 July closure (ADF&G Emergency Order 1-29-03). The closure was ordered because the subsistence harvest up to the closure date greatly exceeded the escapement. Daily totals of between 100–450 sockeye salmon were harvested on at least eight days prior to the closure, and nearly the entire harvest was taken before 25 July (Figure 4). When a large number of salmon entered the freshwater following rain and rising water levels, the first emergency order was rescinded by a new emergency order re-opening subsistence fishing in Klag Bay from 2-31 August (ADF&G Emergency Order 1-S-50-03). However, very few fish were harvested during the later opening.

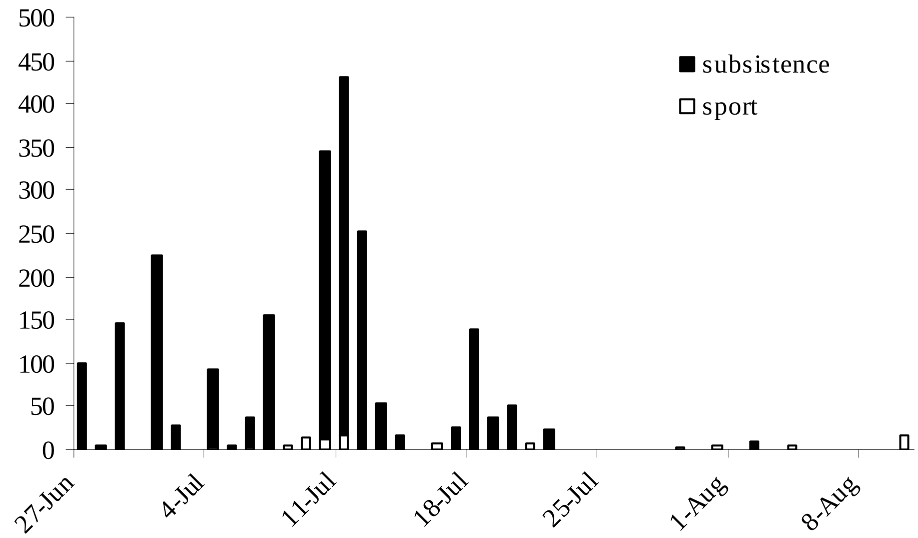


**Figure 4.–**Daily harvest of sockeye salmon in the subsistence and sport fisheries at Klag Bay terminal area, 2003.

The total estimated subsistence harvest was 2,377 (SE=236) sockeye salmon, rounded to 2,400 (SE=240) and the total estimated sport harvest was 111 sockeye salmon (SE=8), rounded to 100 (SE=10; Table 7). A few chum, pink, and coho salmon were also harvested incidentally. Out of 55 sport and subsistence fishing boats counted in the area, the crew interviewed 50 fishers. Approximately half the fishers used gillnets and the other half used seine nets (Table 7).

**Table 7.–**Boat groups counted and interviewed in subsistence and sport harvest surveys and estimated harvest of salmon, by gear type, at the Klag Bay terminal area in 2003.

| Gear Type | Boats Counted | Boats Interviewed | Sockeye | Chum | Pink | Coho |
|---|---|---|---|---|---|---|
| **Seine** | 13 | 12 | 1,205 (141) | 3 (1) | 10 (3) | 1 |
| **Gillnet** | 15 | 13 | 1,172 (95) | 14 (4) | 12 (2) | 22 (5) |
| **Sport** | 27 | 25 | 111 (8) | 3 (1) | 0 | 5 (1) |
| **Total, subsistence** | 28 | 25 | 2,377 (236) | 17 (4) | 21 (5) | 23 (5) |
| **Total, all gear** | 55 | 50 | 2,488 (244) | 20 (5) | 21 (5) | 28 (6) |

Note: Estimated standard errors (SE) of the harvest estimates are indicated in parentheses next to each estimate.

## LIMNOLOGY SAMPLING

### Light, Temperature, and Dissolved Oxygen Profiles

The 2003 seasonal average euphotic zone depth (EZD) was 4.6 m and remained fairly consistent throughout the season (Table 8).

**Table 8.–**Euphotic zone depths in Klag Lake, 2003.

| Sampling Date | EZD (m) |
|---|---|
| 29 June | 4.7 |
| 6 August | 4.6 |
| 12 September | 4.6 |
| Seasonal Average | 4.6 |

Klag Lake was thermally stratified throughout the 2003 summer season. The thermocline had developed between 6 and 8 m by the 29 June sampling date, and persisted through the 12 September sampling date (Figure 5).

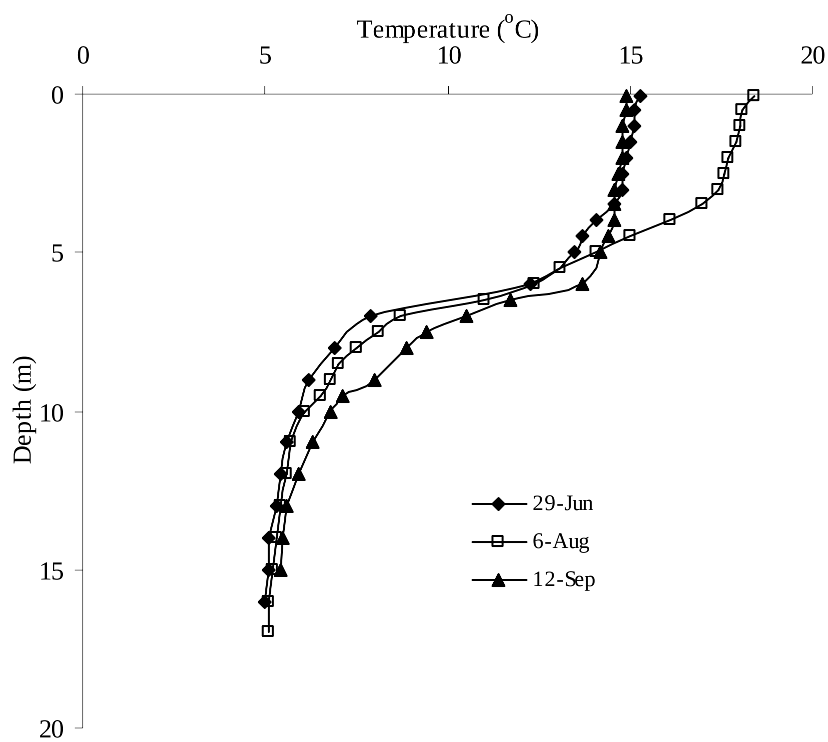


**Figure 5.–**Water column temperature profiles in Klag Lake 2003.

Dissolved oxygen levels in Klag Lake varied from 86–87% saturation just below the surface to a minimum of 59% saturation at 7 m on 12 September (Table 9). At depths below 5 m, dissolved oxygen levels declined through the season.

**Table 9.–**Water column dissolved oxygen profiles in Klag Lake, 2003.

| | Percent oxygen saturation, by date | | |
|---|---|---|---|
| **Depth (m)** | **29-Jun** | **6-Aug** | **12-Sep** |
| 0.05 | 87.4 | 85.9 | 86.0 |
| 1.0 | 86.5 | 86.1 | 82.9 |
| 2.0 | 82.7 | 80.2 | 82.1 |
| 3.0 | 83.3 | 80.8 | 79.1 |
| 4.0 | 82.6 | 73.0 | 78.4 |
| 5.0 | 82.1 | 67.1 | 73.6 |
| 6.0 | 81.7 | 69.2 | 70.6 |
| 7.0 | 81.3 | 75.0 | 58.7 |
| 8.0 | 84.3 | 76.4 | 62.7 |
| 9.0 | 79.3 | 76.8 | 66.5 |
| 10.0 | 81.0 | 75.1 | 67.4 |
| 11.0 | 79.2 | 75.8 | 68.1 |
| 12.0 | 75.2 | 76.0 | 67.7 |
| 13.0 | 78.9 | 74.1 | 68.2 |
| 14.0 | 78.5 | 73.8 | 67.9 |
| 15.0 | 78.6 | 73.5 | 67.9 |
| 16.0 | 77.8 | 74.7 | |
| 17.0 | | 70.9 | |

## Secondary Production

As in previous years, the zooplankton assemblage in Klag Lake was dominated by the small cladoceran *Bosmina* sp., which comprised nearly 75% of zooplankton numbers (Table 10). The copepods *Cyclops* sp. and *Epischura* comprised most of the remaining zooplankton assemblage. The large cladoceran *Daphnia longiremis*, which is a preferred prey for sockeye fry (A. Mazumder, University of Victoria, personal communication), made up only about 1% of the zooplankton assemblage in Klag Lake.

**Table 10.–**Density (numbers per $m^2$) of macrozooplankton, by taxon, in Klag Lake, 2003, averaged between Stations A and B.

| | Density (1000s· $m^{-2}$), by sampling date | | | | |
|---|---|---|---|---|---|
| | **29-Jun** | **6-Aug** | **12-Sep** | **Seasonal Mean** | **Percent of Total** |
| *Bosmina* | 174 | 212 | 62 | 149 | 74% |
| Ovig. *Bosmina* | 0 | 0 | 0 | 0 | 0% |
| *Daphnia longirermis* | 2 | 1 | 2 | 2 | 1% |
| Ovig. *D. longirermis* | 1 | 0 | 0 | 1 | 0% |
| *Holopedium* | 3 | 0 | 1 | 1 | 1% |
| Ovig. *Holopedium* | 0 | 0 | 0 | 0 | 0% |
| *Cyclops* | 52 | 29 | 15 | 32 | 16% |
| Ovig. *Cyclops* | 16 | 2 | 1 | 7 | 3% |
| *Epischura* | 13 | 12 | 10 | 11 | 6% |
| **Seasonal Mean Density, All Taxa** | | | | **203** | |

Note: Ovigerous (egg-bearing) individuals in each taxa were measured separately.

The cladocerans in the Klag Lake zooplankton assemblage were very small, and because the copepods were much larger, on average, they comprised the majority of the zooplankton biomass (Table 11). At only 0.3 mm in length, the *Bosmina* are smaller than optimum prey size for sockeye fry. *Daphnia* are preferred because of their larger size, but the average length of *Daphnia* in the Klag Lake assemblage was small for this species.

**Table 11.–**Size and biomass of macrozooplankton in Klag Lake, 2003, averaged between Stations A and B.

| | Average length (mm) | | | | | |
|---|---|---|---|---|---|---|
| | **29 Jun** | **6 Aug** | **12 Sep** | **Weighted mean length (mm)** | **Weighted biomass ($mg \cdot m^{-2}$)** | **Percent of total biomass** |
| *Bosmina* | 0.31 | 0.28 | 0.32 | 0.30 | 120.60 | 38.1% |
| Ovig. *Bosmina* | 0.62 | | 0.39 | 0.39 | 0.10 | 0.0% |
| *Daphnia longirermis* | 0.66 | 0.63 | 0.60 | 0.63 | 3.07 | 1.0% |
| Ovig. *D. longirermis* | 1.02 | 0.83 | 0.84 | 0.93 | 2.41 | 0.8% |
| *Holopedium* | 0.52 | 0.51 | 0.51 | 0.53 | 3.43 | 1.1% |
| Ovig. *Holopedium* | 0.59 | 0.61 | 0.60 | 0.60 | 0.71 | 0.2% |
| *Cyclops* | 0.92 | 0.78 | 0.75 | 0.83 | 79.70 | 25.2% |
| Ovig. *Cyclops* | 1.19 | 0.96 | 0.83 | 1.14 | 31.07 | 9.8% |
| *Epischura* | 1.35 | 1.00 | 1.12 | 1.15 | 75.18 | 23.8% |
| **Total Seasonal Mean Biomass** | | | | | 316.3 | |

Note: Mean lengths are weighted by density (numbers · $m^{-2}$) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigerous (egg-bearing) individuals in each taxa were measured separately.

# DISCUSSION

We met all objectives for the Klag Lake sockeye salmon project from 2001 to 2003 and have produced estimates of sockeye harvest and escapement in the Klag Lake system that are contributing to better management of the fishery in this system. In addition, we gathered supporting information, including adult sockeye age compositions, sockeye fry and stickleback population estimates, zooplankton biomass estimates, and water column light, temperature, and dissolved oxygen profiles.

The returns of sockeye salmon to the Klag Lake system appeared to be able to support an intense harvest in the terminal area at the same time as allowing 85–91% of the total return to escape into the lake to spawn (Table 12). From 2001–2003, the total return of sockeye salmon to Klag Lake increased each year. The number of sockeye salmon escaping into Klag Lake exceeded the number harvested in the marine terminal area by 6–10 times over the three years of this study. The total sockeye harvest fluctuated around an average of about 2,400 sockeye salmon. Total harvests reported by subsistence users who returned their permits to ADF&G were roughly the same as the harvest estimates generated from our on-site surveys. In 2002, the harvest reported by permit holders exceeded the on-site estimate of sockeye salmon by 25%. This indicates that the interviewers did not observe all the boats fishing in the bay. Although the reported sockeye harvest in 2003 was also less than the on-site estimate of harvest, improvements to the protocol in 2003 narrowed the difference substantially (Table 12). Despite the accurate reporting on ADF&G subsistence permits, we recommend that the on-site fishery interviews continue so that managers have an in-season estimate of the total return to Klag Bay, can protect the early part of the run from being over-fished, and can close and open the fishery in-season if are necessary.

**Table 12.–**Summary of escapement and harvest estimates for Klag Lake sockeye salmon, 2001–2003.

| Year | Total return | Escapement | Total Harvest: On-site survey | Total Harvest: Returned permits | Percent of total return attributed to escapement |
|---|---|---|---|---|---|
| 2001 | 13,700 | 12,000 | 1,700 | 1,300 | 88% |
| 2002 | 20,000 | 17,000 | 3,000 | 4,000 | 85% |
| 2003 | 25,400 | 23,000 | 2,400 | 2,500 | 91% |

Note: Harvest estimates collected on-site are considered more accurate than ADF&G subsistence permit records. However, the 2002 Klag Lake on-site survey was considerably less than the reported harvest on the permits, which indicates that the interviewers did not observe all the boats.

The high harvest of sockeye salmon at the beginning of the run in Klag Bay did cause the marine terminal area fisheries close early in 2002 and 2003. By the third week in July, in both years, total sockeye harvests greatly exceeded the numbers of sockeye salmon that had escaped into the Klag Lake stream. The fish stayed in the bay during a period in July when the weather was dry and water in the stream was low. Consequently, large schools of sockeye salmon in Klag Bay were vulnerable to fishing nets and hooks during periods of low water. The subsistence and sport fisheries were closed by emergency order before the end of July as a precaution until more sockeye salmon started moving into the stream. Surges in escapement, coinciding with increasing water levels in the stream in both years, raised cumulative escapement numbers enough that managers were willing to reopen the fisheries in August. However, not many fish were harvested after the closure, despite the abundance of sockeye salmon returning to Klag Lake in both years.

The timing of the subsistence sockeye harvest with respect to the timing of escapement could be important if subsistence fishers disproportionately remove more sockeye salmon during the beginning of the season. Subsistence sockeye fishing usually takes place starting in late June to early July in Southeast Alaska, and usually does not continue much beyond early August. The typical harvest season at Klag Bay was shorter and ended earlier than the season in the overall Sitka management area, according to subsistence users' reports from 1985–2000 (Table 13). The timing of the Klag Bay harvest surveys in 2001–2003 appears to be similar to the reported harvest timing for 1985–2000. Escapement timing at the Klag Lake weir in 2001–2003 was relatively late compared with the usual harvest timing (Lorrigan et al. 2004; Conitz and Cartwright 2002; Tables 13 and 14). In some years, the subsistence fishers could have taken the total return of sockeye salmon before the first one-quarter of the run had escaped into the stream in 2001–2003. The first quartile was particularly late in 2002 (8 August) although by the following day half of the run had entered the stream. Escapement timing into the Klag Lake stream appeared to be dominated by large surges of fish on a few days, coinciding with peak water levels in the stream in late July to mid-August. The concern from a fisheries management viewpoint is that a large proportion of a given year's sockeye run could potentially be harvested in low water conditions when return spawners are staging in the bay. If these fish arrive, enter the system, and spawn earlier than others, harvest of a major proportion of these fish could alter the genetic makeup of the stock with respect to timing.

**Table 13.–**Reported dates of subsistence sockeye harvest in the Sitka management area, which includes Klag Bay, and reported harvest dates for Klag Bay.

| Subsistence Harvest 1985–2000 | | First harvest date | Midpoint | Last harvest date |
|---|---|---|---|---|
| **Sitka area-all** | Date range | 7 April–27 June | 20–31 July | 15 Aug–8 Dec |
| | Median date | 15 June | 26 July | 26 Aug |
| **Klag Bay** | Date range | 19 June–29 July | 11–30 July | 26 July–20 Aug |
| | Median date | 1 July | 19 July | 4 Aug |

Note: Dates were reported on returned subsistence permits and were not independently verified (ADF&G Division of Commercial Fisheries database 2005).

**Table 14.–**Summary of sockeye run timing through the Klag Lake weir, 2001–2003.

| Year | 2001 | 2002 | 2003 |
|---|---|---|---|
| First count | 6 Jul | 4 Jul | 28 Jun |
| First quartile | 26 Jul | 8 Aug | 30 Jul |
| Midpoint | 15 Aug | 9 Aug | 3 Aug |
| Third quartile | 27 Aug | 15 Aug | 15 Aug |
| Last count | 9 Sep | 11 Sep | 12 Sep |

Source: (Conitz and Cartwright 2002; Lorrigan et al. 2004; Appendix B).

Although the Klag Lake sockeye population appears to be healthy, the spawning habitat is not considered ideal for salmon. The substrate is comprised mainly of large immovable angular cobble and bedrock. Sockeye spawners jostle amongst themselves for any space over the stream bottom in which to broadcast their eggs. Foerster (1968) described similar habitat on the Skeena River, where he observed sockeye spawners broadcasting their eggs into cracks and interstices of the creek bottom. Furthermore, the inlet stream is very short—creating a high density of spawners in this stream. Apparently, subsequent waves of spawners cause little disturbance of redds, and the fertilized eggs are layered on top of each other.

We estimated sockeye fry populations in only two years, 2001 and 2002. Because escapement was not estimated in 2000, only one fry estimate can be linked to the parent-year escapement estimate (2002 fry population with 2001 escapement). We will not have estimates of returns from these fry populations until 2004–2007.

In addition to sockeye fry, three sticklebacks are a prominent part of the freshwater community in Klag Lake—in some years outnumbering sockeye fry (Table 15). Sockeye fry are selective feeders, targeting larger and slower-moving cladocerans (*Daphnia)* whenever possible (Koenings et al. 1987). Because sticklebacks and sockeye fry reside in the pelagic area of lakes and are both planktivores, the competition between stickleback and sockeye fry could potentially limit sockeye production in Klag Lake (Beauchamp and Overman 2003). Indeed, the low number of *Daphnia* in Klag Lake compared to the higher number of the smaller cladoceran (*Bosmina*) and copepods (Table 16; Appendix C) suggest that the grazing pressure on the larger cladocerans is high. However, compared with other small sockeye rearing lakes in Southeast Alaska in 2002, Klag Lake produced relatively high numbers of large fry (Table 17). This implies that the zooplankton resource is adequate in Klag Lake at the current levels of planktivore (stickleback and sockeye fry) abundance.

**Table 15. –**Estimated numbers of sockeye fry and sticklebacks in Klag Lake, 2001 and 2002, based on the estimated total number of acoustic targets and the proportion of each species found in trawl samples.

| Year | Total sockeye ($n_{so}$) | Total sticklebacks ($n_{st}$) | All fish ($n$) |
|---|---|---|---|
| 2001 | 54,000 (38) | 195,000 (138) | 249,000 (176) |
| 2002 | 127,000 (136) | 62,000 (66) | 188,000 (202) |

Note: Trawl sample sizes ($n$) and numbers of sockeye fry ($n_{so}$) and sticklebacks ($n_{st}$) in the samples are shown in parentheses next to the population estimate.

**Table 16.–**Comparison of pelagic fish populations and zooplankton population characteristics in Klag Lake in 2001–2003.

| | Zooplankton seasonal mean biomass (mg·m$^{-2}$) | | |
|---|---|---|---|
| Year | Total | *Daphnia* | *Daphnia* length (mm) |
| 2001 | 175 | 3 | 0.76 |
| 2002 | 222 | 5 | 0.81 |
| 2003 | 316 | 5 | 0.70 |

Another indication of sufficient food resources is the age at which the sockeye smolt leave the lake. In general, sockeye juveniles will emigrate from their rearing lake if they achieve sufficient growth in their first year (Koenings et al. 1987). The majority of sockeye smolt that migrated from Klag Lake were age 1 (Table 18). However, the proportion of age 2 smolt increased between 2001 and 2003 (Table 18). This trend towards older smolts coupled with the low abundance of *Daphnia* suggests that the planktivore populations in Klag Lake may be approaching their carrying capacity at these abundance levels. Moreover, in years when stickleback survival is high, sockeye production could be limited by food.

**Table 17.–**Sockeye fry densities and average weights of age-0 fry in selected Southeast Alaska lakes with important subsistence runs, 2002.

| Lake | Date sampled | Fry·100 $m^{-2}$ | Av. wt. age-0 fry (g) |
|---|---|---|---|
| Hetta | Jul 18 | 44 | 0.3 |
| Kutlaku | Aug 9 | 41 | 1.1 |
| Gut Bay | Aug 23 | 25 | 0.5 |
| Klag | Aug 25 | 23 | 1.1 |
| Luck | Jul 22 | 23 | 0.4 |
| Hoktaheen | Oct 13 | 18 | 1.4 |
| Sitkoh | Aug 13 | 11 | 1.1 |
| Klawock I | Jul 17 | 4 | 0.6 |
| Kanalku | Aug 10 | 3 | 1.0 |
| Klawock II | Oct 2 | 3 | 1.8 |
| Falls | Aug 24 | 2 | 0.7 |
| Kook | Aug 11 | 2 | 0.8 |
| Salmon Bay | Sep 22 | 2 | 1.0 |

Note: Fry density is the estimated number of fry per 100 $m^2$ of lake surface area. Average weights of age-0 fry vary with sample date; in general, fry sampled later in the have larger average weights than fish sampled at the beginning of the season.

**Table 18.–**Age composition of adult sockeye salmon in the Klag Lake escapement, 2001–2003.

| Age: | 1.1 | 1.2 | 1.3 | 1.4 | 2.1 | 2.2 | 2.3 | 2.4 | Sample Size |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | 7.5% | 25.1% | 55.8% | 0.1% | 2.7% | 4.7% | 3.8% | 0.2% | 991 |
| **2002** | 0.6% | 27.5% | 44.2% | 0.1% | 1.4% | 16.9% | 9.2% | | 697 |
| **2003** | 3.9% | 22.9% | 36.5% | | 1.3% | 19.7% | 15.7% | | 638 |
| **Mean** | 4% | 25.2% | 45.5% | 0.1% | 1.8% | 13.8% | 9.6% | 0.1% | |

We concluded that over-harvest was not a problem for the Klag Lake sockeye runs in 2001–2003, but the timing of the escapement, especially at the beginning of the run, needs to be watched carefully. Some in-season restrictions on the subsistence fishery may be necessary to protect the early part of the sockeye run. If increased escapements do not produce higher returns because of production limitations in the lake, there is no advantage to further restricting overall harvest. In fact, fishery managers could consider increasing harvest opportunities. However, in order to determine if sockeye production is limited in freshwater, researchers will need to estimate the smolt production from each parent year. At minimum, we recommend continued monitoring of the sport and subsistence fisheries and the escapement in the Klag Lake system, to build on the three years of baseline information presented here.

# ACKNOWLEDGEMENTS

We wish to acknowledge the many people in all three cooperating agencies, the Sitka Tribe of Alaska (STA), the Alaska Department of Fish and Game (ADF&G), and the U.S. Forest Service (USFS), who played a vital role in the completion of this project. Doug Dobyns of STA supervised the fieldwork and data collection during the third year of the project. Terry Suminski of the USFS, Sitka Ranger District, provided the necessary land use permits and reviewed and provided input into field data collection procedures. Zachary Penny served as the crew leader at Klag Bay and was responsible for collecting and summarizing the weir and harvest survey data. Thomas Miller, Rich Didrickson, Kim Perkins, and Doug Dobyns of STA were capable crewmembers. Paul Hill and Helen Dangel of STA provided expert computer advice.

We also acknowledge the expert assistance of the following groups and individuals at ADF&G: John Edmondson and the Soldotna Limnology Lab crew for processing of the zooplankton samples; Iris Frank, Mark Olsen, and the Commercial Fisheries Scale & Age Lab crew for analysis of scale, length, and age data; Xinxian Zhang for advice and programming for statistical analysis; Renate Riffe for the subsistence harvest analysis; and Jim Craig for publication assistance. Hal Geiger, ADF&G Salmon Research Coordinator; Matt Foster, ADF&G fisheries biologist; Doug McBride, US Fish and Wildlife Service, fisheries biologist provided excellent review comments of the report and technical advice. We thank Ken Bellows of Air Sitka, the pilots of Harris Air, and the hardworking crew of the *M/V Silver Arrow* for safely transporting people and gear to the field site. Finally, we wish to thank the subsistence and sport fishers and members of the Sitka Tribe of Alaska who took part in the harvest interviews, and whose interest in the continuing use and conservation of the Klag Bay sockeye runs provide the motivation for this project.

# REFERENCES CITED


Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1995. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 2106, 37 pp. www.cs.umanitoba.ca/~popan

Beauchamp, D. A., and N. C. Overman. 2003. Influence of fertilization on juvenile sockeye salmon growth and production in Redoubt Lake, Alaska. Washington Cooperative Fish and Wildlife Research Unit Report No. WACFWRU-03-03. U.S. Geological Survey, Seattle, Washington.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, New Westminster, British Columbia.

Cochran, W. G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons Inc. New York, NY.

Conitz, J., M. Cartwright, and B. Van Alen. 2002. Falls Lake sockeye salmon stock assessment. Regional Information Report No. 1J02-33. Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, Alaska.

Conitz, J., and M. Cartwright. 2002. Klag Bay sockeye salmon stock assessment. Regional Information Report No. 1J02-28. Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, Alaska.

Conitz, J. and M. Cartwright. 2003. Falls, Gut Bay, and Kutlaku Lakes subsistence sockeye salmon project, 2002 Annual Report. Regional Information Report No. 1J03-42. Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, Alaska.

Foerster, R. E. 1968. The sockeye salmon, *Oncorhynchus nerka*. Bulletin Fisheries Research. Board Canada 162: 422.

Geiger, H. J. 2003. Sockeye salmon stock status and escapement goal for Redoubt Lake in Southeast Alaska. Regional Information Report No. 1J03-01. Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, Alaska.

Goldschmidt, W. R., T. H. Haas, and T. F. Thornton. 1998. Haa aaní, Our Land: Tlingit and Haida Land Rights and Use. Sealaska Heritage Foundation, Juneau; University of Washington Press, Seattle. 219 pp.

Kirk, J. T. 0. 1994. Light and photosynthesis in aquatic ecosystems. Cambridge University Press. England.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, J. M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development. Report No. 71, Juneau, Alaska.

Koo, T. S. Y. 1962. Age designation in salmon. In *Studies of Alaska Red Salmon*. University of Washington Press, Seattle.

Lewis, B. A. and M. A. Cartwright. 2004. Hetta Lake sockeye salmon stock assessment project: 2002 annual report. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report 1J04-10. Juneau, Alaska.

Lorrigan J., M Cartwright, and J. Conitz. 2004. Klag Bay sockeye stock assessment. Regional Information Report No. 1J04-18. Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, Alaska.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, British Columbia.

Orth, D. J. 1971. Dictionary of Alaska Place Names. Professional Paper No. 567, U.S. Geological Survey, Washington, D.C.

Pearson, E. S. and H. O. Hartley, eds. 1966. Biometrika Tables for Statisticians, Vol. 1. Cambridge University Press, Cambridge, England.

Rich, W. H. and E. M. Ball. 1933. Statistical review of the Alaska salmon fisheries. Part IV: Southeastern Alaska. Bulletin of the Bureau of Fisheries, Vol. 47 (13): 437–673.

Schindler, D. W. 1971. Light, temperature, and oxygen regimes of selected lakes in the experimental lakes area, northwestern Ontario. J. Fish. Res. Bd. Canada. 28: 157–169.

Seber, G. A. F. 1982. The estimation of animal abundance, 2nd ed. Griffen, London. 654 pp.

Thompson, S. K. 1992. Sampling. Wiley-Interscience, New York. 343 pp.

# APPENDICES

**Appendix A.**–Number of permits, total annual harvests, and average number of sockeye salmon harvested per permit, reported by Klag Bay subsistence permit holders, 1985–2003.

| Year | Number of permits | Total sockeye harvest | Number of sockeye per permit |
|---|---|---|---|
| 1985 | 29 | 582 | 20 |
| 1986 | 46 | 919 | 20 |
| 1987 | 42 | 816 | 19 |
| 1988 | 26 | 629 | 24 |
| 1989 | 5 | 114 | 23 |
| 1990 | 5 | 115 | 23 |
| 1991 | 1 | 23 | 23 |
| 1992 | 11 | 276 | 25 |
| 1993 | 59 | 1,626 | 28 |
| 1994 | 31 | 809 | 26 |
| 1995 | 28 | 1,098 | 39 |
| 1996 | 100 | 3,381 | 34 |
| 1997 | 42 | 1,106 | 26 |
| 1998 | 33 | 834 | 25 |
| 1999 | 42 | 1,048 | 25 |
| 2000 | 48 | 1,082 | 23 |
| 2001 | 65 | 1,325 | 20 |
| 2002 | 94 | 4,065 | 43 |
| 2003 | 70 | 2,475 | 35 |
| **average 1985–1993** | 25 | 567 | 23 |
| **average 1994–2003** | 55 | 1,722 | 30 |

Note: ADF&G compiles harvest information from subsistence permit holders who return this information with their permit. This is not necessarily an accurate accounting of the total subsistence sockeye harvest at Klag Bay.

**Appendix B.–**Annual harvest of sockeye, chum, and pink salmon, and effort in terms of numbers of boats and total hours fished, in the Khaz Bay seine fishery, 1969–2004.

| Year | Annual harvest by species | | | Number of boats | Total hours fished |
|---|---|---|---|---|---|
| | Sockeye | Chum | Pink | | |
| 1969 | 22 | 538 | 17,447 | 14 | 330 |
| 1970 | | | | 0 | 288 |
| 1971 | 14 | 1,036 | 24,602 | 5 | 360 |
| 1972 | | | | 0 | 336 |
| 1973 | 0 | 0 | 0 | 0 | 288 |
| 1974 | 0 | 0 | 0 | 0 | 234 |
| 1975 | 0 | 0 | 0 | 0 | 132 |
| 1976 | 0 | 0 | 0 | 0 | 54 |
| 1977 | 0 | 0 | 0 | 0 | 210 |
| 1978 | 0 | 0 | 0 | 0 | 141 |
| 1979 | 0 | 0 | 0 | 0 | 363 |
| 1980 | 0 | 269 | 4,629 | 4 | 150 |
| 1981 | 411 | 16,792 | 372,627 | 60 | 399 |
| 1982 | 73 | 1,759 | 110,094 | 20 | 336 |
| 1983 | 351 | 3,302 | 155,351 | 16 | 447 |
| 1984 | 93 | 26,079 | 126,510 | 27 | 312 |
| 1985 | 702 | 12,630 | 435,104 | 31 | 486 |
| 1986 | 312 | 13,712 | 55,114 | 22 | 321 |
| 1987 | 155 | 2,162 | 16,497 | 7 | 123 |
| 1988 | 104 | 9,041 | 1,250 | 14 | 60 |
| 1989 | 766 | 12,600 | 126,394 | 24 | 447 |
| 1990 | 185 | 2,144 | 12,792 | 4 | 294 |
| 1991 | 471 | 10,005 | 149,099 | 14 | 624 |
| 1992 | 529 | 82,592 | 204,105 | 28 | 405 |
| 1993 | 131 | 9,474 | 2,168 | 7 | 265 |
| 1994 | 837 | 29,732 | 485,433 | 26 | 303 |
| 1995 | 541 | 52,211 | 613,509 | 49 | 156 |
| 1996 | 1,534 | 13,648 | 243,283 | 20 | 465 |
| 1997 | 1,960 | 8,756 | 74,874 | 12 | 389 |
| 1998 | 58 | 9,959 | 158,591 | 14 | 357 |
| 1999 | 194 | 30,344 | 245,267 | 21 | 447 |
| 2000 | 708 | 106,170 | 737,656 | 82 | 255 |
| 2001 | 154 | 15,581 | 235,758 | 19 | 366 |
| 2002 | 122 | 60,140 | 611,383 | 53 | 354 |
| 2003 | 396 | 28,790 | 450,986 | 22 | 678 |
| 2004 | 366 | 29,222 | 630,376 | 32 | 480 |
| **Average** | **329** | **17,314** | **185,321** | **18** | **324** |

**Appendix C.–**Numbers of fish counted by species, numbers of sockeye salmon sampled for scales, length, and sex, numbers of sockeye salmon marked for mark-recapture experiment, and daily water level and temperature, at the Klag Lake weir, 2003. Marks given were clips to left axillary (LA), left ventral (LV), and dorsal (D) fins; adipose fins were also clipped on all marked fish.

| | | | Sockeye salmon marked and sampled | | | Numbers of salmon counted, by species | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Water depth (ft) | Water temp (°C) | Mark given | Number marked | Number ASL sampled | Sockeye (daily) | Sockeye (cumulative) | Coho | Pink | Chum |
| 06/24 | 0.90 | 16.0 | | | | | | | | |
| 06/25 | 0.90 | 15.0 | | | | | | | | |
| 06/26 | 0.98 | 15.0 | | | | | | | | |
| 06/27 | 1.14 | 14.0 | | | | | | | | |
| 06/28 | 1.16 | 14.0 | LA | 9 | 9 | 9 | 9 | 0 | 0 | 0 |
| 06/29 | 1.10 | 14.0 | LA | 1 | 1 | 1 | 10 | 0 | 0 | 0 |
| 06/30 | 1.02 | 16.0 | LA | 3 | 3 | 3 | 13 | 0 | 0 | 0 |
| 07/01 | 0.92 | 17.0 | LA | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| 07/02 | 0.86 | 16.0 | LA | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| 07/03 | 0.85 | 15.0 | LA | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| 07/04 | 1.30 | 15.0 | LA | 3 | 0 | 3 | 16 | 0 | 0 | 0 |
| 07/05 | 1.20 | 17.0 | LA | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| 07/06 | 0.95 | 16.0 | LA | 21 | 20 | 21 | 37 | 0 | 0 | 0 |
| 07/07 | 0.86 | 16.0 | LA | 1 | 1 | 1 | 38 | 0 | 0 | 0 |
| 07/08 | 0.80 | 17.0 | LA | 15 | 15 | 16 | 54 | 0 | 0 | 0 |
| 07/09 | 0.74 | 18.0 | LA | 0 | 0 | 0 | 54 | 0 | 0 | 0 |
| 07/10 | 0.70 | 18.0 | LA | 0 | 0 | 0 | 54 | 0 | 0 | 0 |
| 07/11 | 0.66 | 19.0 | LA | 0 | 0 | 0 | 54 | 0 | 0 | 0 |
| 07/12 | 0.63 | 19.0 | LA | 2 | 2 | 2 | 56 | 0 | 0 | 0 |
| 07/13 | 0.62 | 19.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/14 | 0.60 | 18.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/15 | 0.59 | 18.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/16 | 0.58 | 17.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/17 | 0.59 | 17.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/18 | 0.59 | 17.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/19 | 0.60 | 18.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |

-continued-

| | | | Sockeye salmon marked and sampled | | | Numbers of salmon counted, by species | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Water depth (ft)** | **Water temp ($^oC$)** | **Mark given** | **Number marked** | **Number ASL sampled** | **Sockeye (daily)** | **Sockeye (cumulative)** | **Coho** | **Pink** | **Chum** |
| 07/20 | 0.62 | 18.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/21 | 0.66 | 17.0 | LA | 0 | 0 | 0 | 56 | 0 | 0 | 0 |
| 07/22 | 0.80 | 17.0 | LA | 78 | 40 | 126 | 182 | 2 | 0 | 0 |
| 07/23 | 0.84 | 17.0 | LA | 40 | 16 | 42 | 224 | 28 | 0 | 0 |
| 07/24 | 0.82 | 18.0 | LA | 18 | 4 | 34 | 258 | 0 | 0 | 0 |
| 07/25 | 0.76 | 17.0 | LA | 19 | 10 | 20 | 278 | 0 | 0 | 0 |
| 07/26 | 0.72 | 17.0 | LV | 20 | 20 | 74 | 352 | 0 | 1 | 0 |
| 07/27 | 0.72 | 16.0 | LV | 0 | 0 | 28 | 380 | 1 | 0 | 0 |
| 07/28 | 0.72 | 17.0 | LV | 0 | 0 | 3 | 383 | 0 | 0 | 0 |
| 07/29 | 1.60 | 16.0 | LV | 450 | 70 | 4,683 | 5,066 | 187 | 84 | 1 |
| 07/30 | 1.22 | 17.0 | LV | 637 | 40 | 2,734 | 7,800 | 213 | 101 | 1 |
| 07/31 | 1.02 | 17.0 | LV | 450 | 40 | 1,218 | 9,018 | 55 | 19 | 0 |
| 08/01 | 0.98 | 17.0 | LV | 597 | 40 | 674 | 9,692 | 33 | 21 | 0 |
| 08/02 | 0.96 | 17.5 | LV | 50 | 40 | 1,211 | 10,903 | 71 | 61 | 0 |
| 08/03 | 1.16 | 16.5 | LV | 89 | 40 | 658 | 11,561 | 76 | 47 | 0 |
| 08/04 | 0.90 | 17.0 | LV | 40 | 40 | 653 | 12,214 | 14 | 67 | 0 |
| 08/05 | 1.00 | 17.0 | LV | 32 | 10 | 471 | 12,685 | 42 | 64 | 0 |
| 08/06 | 0.90 | 16.0 | LV | 33 | 10 | 565 | 13,250 | 25 | 44 | 2 |
| 08/07 | 0.89 | 17.0 | LV | 108 | 10 | 401 | 13,651 | 9 | 57 | 0 |
| 08/08 | 0.84 | 18.0 | LV | 80 | 10 | 213 | 13,864 | 5 | 13 | 0 |
| 08/09 | 0.78 | 19.0 | LV | 67 | 10 | 191 | 14,055 | 1 | 21 | 0 |
| 08/10 | 0.72 | 16.5 | LV | 38 | 10 | 183 | 14,238 | 3 | 14 | 0 |
| 08/11 | 0.68 | 19.0 | D | 10 | 10 | 54 | 14,292 | 1 | 2 | 0 |
| 08/12 | 0.66 | 17.0 | D | 0 | 0 | 6 | 14,298 | 1 | 1 | 0 |
| 08/13 | 0.68 | 16.5 | D | 62 | 10 | 201 | 14,499 | 48 | 11 | 0 |
| 08/14 | 0.72 | 16.5 | D | 191 | 10 | 917 | 15,416 | 535 | 338 | 0 |
| 08/15 | 1.38 | 16.0 | D | 387 | 10 | 4,331 | 19,747 | 350 | 5883 | 0 |
| 08/16 | 1.80 | 15.0 | D | 68 | 10 | 792 | 20,539 | 162 | 3555 | 0 |
| 08/17 | 1.72 | 15.5 | D | 157 | 10 | 169 | 20,708 | 125 | 987 | 0 |
| 08/18 | 1.54 | 15.5 | D | 149 | 10 | 159 | 20,867 | 131 | 777 | 1 |
| 08/19 | 1.26 | 15.0 | D | 98 | 10 | 98 | 20,965 | 105 | 386 | 0 |

-continued-

**Appendix C.–**Page 3 of 3.

| Date | Water depth (ft) | Water temp (°C) | Sockeye salmon marked and sampled: Mark given | Number marked | Number ASL sampled | Numbers of salmon counted, by species: Sockeye (daily) | Sockeye (cumulative) | Coho | Pink | Chum |
|---|---|---|---|---|---|---|---|---|---|---|
| 08/20 | 1.26 | 15.0 | D | 166 | 10 | 166 | 21,131 | 135 | 331 | 0 |
| 08/21 | 1.20 | 15.0 | D | 92 | 10 | 92 | 21,223 | 100 | 308 | 0 |
| 08/22 | 1.10 | 14.5 | D | 47 | 10 | 48 | 21,271 | 56 | 55 | 0 |
| 08/23 | 0.90 | 13.5 | D | 41 | 10 | 41 | 21,312 | 17 | 62 | 0 |
| 08/24 | 0.88 | 14.5 | D | 83 | 10 | 85 | 21,397 | 19 | 262 | 0 |
| 08/25 | 0.80 | 14.0 | D | 70 | 10 | 72 | 21,469 | 25 | 163 | 0 |
| 08/26 | 0.76 | 14.0 | D | 23 | 8 | 24 | 21,493 | 7 | 38 | 0 |
| 08/27 | 0.72 | 15.0 | D | 2 | 2 | 27 | 21,520 | 8 | 127 | 0 |
| 08/28 | 0.74 | 14.0 | D | 0 | 0 | 16 | 21,536 | 2 | 65 | 0 |
| 08/29 | 0.72 | 15.0 | D | 0 | 0 | 25 | 21,561 | 15 | 55 | 0 |
| 08/30 | 0.72 | 14.5 | D | 51 | 10 | 253 | 21,814 | 24 | 338 | 0 |
| 08/31 | 0.84 | 14.0 | D | 0 | 0 | 107 | 21,921 | 109 | 1013 | 0 |
| 09/01 | 1.04 | 14.0 | D | 0 | 0 | 29 | 21,950 | 29 | 266 | 0 |
| 09/02 | 1.65 | 14.0 | D | 0 | 0 | 675 | 22,625 | 497 | 14574 | 2 |
| 09/03 | 1.62 | 14.0 | D | 23 | 0 | 51 | 22,676 | 79 | 1510 | 3 |
| 09/04 | 1.34 | 14.0 | D | 0 | 0 | 40 | 22,716 | 108 | 606 | 1 |
| 09/05 | 1.06 | 13.0 | D | 13 | 10 | 14 | 22,730 | 46 | 222 | 0 |
| 09/06 | 1.04 | 14.0 | D | 0 | 0 | 9 | 22,739 | 15 | 76 | 0 |
| 09/07 | 0.95 | 14.0 | D | 0 | 0 | 1 | 22,740 | 1 | 66 | 0 |
| 09/08 | 0.90 | 14.0 | D | 0 | 0 | 8 | 22,748 | 10 | 119 | 0 |
| 09/09 | 0.82 | 13.5 | D | 0 | 0 | 11 | 22,759 | 8 | 107 | 0 |
| 09/10 | 0.94 | 14.0 | D | 0 | 0 | 6 | 22,765 | 22 | 145 | 1 |
| 09/11 | 1.10 | 13.5 | D | 0 | 0 | 17 | 22,782 | 33 | 496 | 1 |
| 09/12 | 1.60 | 13.0 | D | 0 | 0 | 17 | 22,799 | 72 | 485 | 0 |
| 09/13 | 1.20 | 13.5 | D | 0 | 0 | 0 | 22,799 | 21 | 75 | 1 |

**Appendix D.–**Seasonal mean biomass of all zooplankton and of *Daphnia* sp. and mean length of *Daphnia* sp. (weighted by abundance) in selected sockeye-producing lakes in Southeast Alaska.

| | 2001 | | | | 2002 | | | | 2003 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zooplankton biomass ($mg \cdot m^{-2}$) | | *Daphnia* length (mm) | | Zooplankton biomass ($mg \cdot m^{-2}$) | | *Daphnia* length (mm) | | Zooplankton biomass ($mg \cdot m^{-2}$) | | *Daphnia* length (mm) |
| **Lake** | **Total** | ***Daphnia*** | | **Lake** | **Total** | ***Daphnia*** | | **Lake** | **Total** | ***Daphnia*** | |
| Sitkoh | 647 | 91 | 0.73 | Hoktaheen* | 618 | 11 | 0.92 | Kutlaku | 620 | 80 | 0.53 |
| Kanalku | 371 | 119 | 0.96 | Sitkoh | 569 | 187 | 0.79 | Tumakof | 493 | 0 | na |
| Salmon Bay | 347 | 62 | 0.92 | Tumakof | 454 | 2 | 0.63 | Klawock | 385 | 32 | 0.98 |
| Hoktaheen* | 316 | 17 | 1.05 | Klawock | 420 | 21 | 0.95 | Kanalku | 372 | 83 | 0.74 |
| Kook | 299 | 37 | 0.88 | Kanalku | 424 | 138 | 0.81 | Salmon Bay | 324 | 26 | 0.77 |
| Luck | 233 | 20 | 0.86 | Kook | 311 | 50 | 0.81 | Klag | 316 | 5 | 0.70 |
| Klawock | 217 | 15 | 0.97 | Luck | 311 | 18 | 0.70 | Luck | 199 | 6 | 0.77 |
| Kutlaku | 177 | 24 | 0.63 | Klag | 222 | 5 | 0.81 | Thoms | 163 | 6 | 0.58 |
| Klag | 175 | 3 | 0.76 | Salmon Bay | 195 | 14 | 0.81 | Eek | 128 | 0 | na |
| Thoms | 143 | 9 | 0.62 | Kutlaku | 130 | 35 | 0.53 | Hetta | 45 | 1 | 0.63 |
| Falls | 104 | 0 | 0.70 | Thoms | 119 | 7 | 0.62 | Falls | 29 | 1 | 0.69 |
| Hetta | 34 | 0 | 0.68 | Hetta | 47 | 5 | 0.70 | Sitkoh | na | na | na |
| Gut | 33 | 1 | 0.62 | Falls | 29 | 1 | 0.74 | Kook | na | na | na |
| | | | | Gut | 20 | 1 | 0.65 | Gut | na | na | na |
| Average | 238 | 31 | 0.80 | Average | 276 | 35 | 0.75 | Average | 279 | 22 | 0.71 |
| Median | 217 | 17 | 0.76 | Median | 267 | 13 | 0.77 | Median | 316 | 6 | 0.70 |